Coupler Processing - Vacuum Aspects

M.Seidel, DESY

November 20, 2003

- **Motivation - Breakdown & Vacuum**
- **Bulk Diffusion**
  - diffusing mechanism
  - baking temperatures and times
- **Surface Outgassing**
  - physical background
  - temperatures and binding energies
- **Procedures and Practical Recommendations**

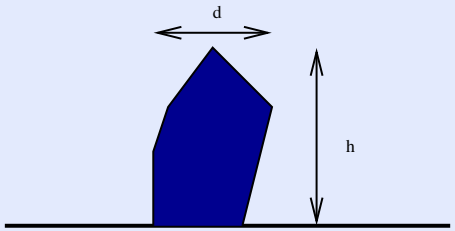
Breakdown Mechanism and Vacuum

electrical breakdown mechanisms are

complicated and not well understood

some common opinions:

- main reason for breakdown: high β_{FN} surface discontinuities or dust particles $E_{\mathrm{peak}} = \beta_{\mathrm{FN}} \cdot E_{\mathrm{avg}}$; roughly: $\beta_{\mathrm{FN}} \propto (h/d)^{1.5\ldots2}$



- thermally isolated dust particles → vaporization, vacuum outburst
- vacuum outburst, ions due to electron bombardment → enhances or amplifies breakdown currents

Breakdown Mechanism cont'd.

outgassing is probably not the primary reason for breakdown, but enhances it or lowers the onset-threshold

after longer conditioning and with higher fields the vacuum effect becomes less important but breakdowns still happen

observed e.g. at surface field levels of 300 to 400 MeV/m; taking into account typical β_{FN} factors the tensile strength of copper is exceeded!

at these field levels no temperature dependence of breakdown limits between 70 K and 570 K was observed!

see paper by W. Wünsch et al. (CLIC), EPAC 2002

Dissolved Gas - Bulk Diffusion

described by diffusion eq.:

$$\frac{\partial}{\partial t}c(x,t) - D\frac{\partial^2}{\partial x^2}c(x,t) = 0$$

diffusion coefficient D
depends on temperature and
gas/material combination

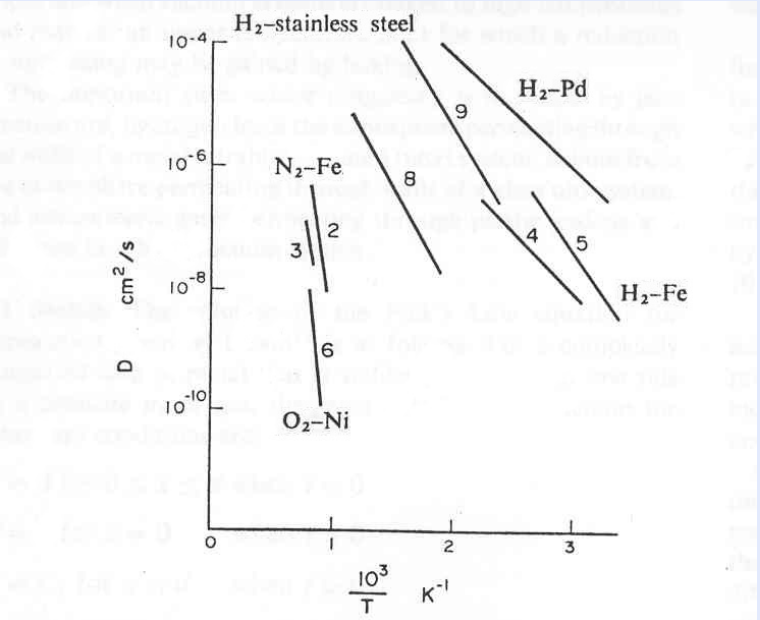
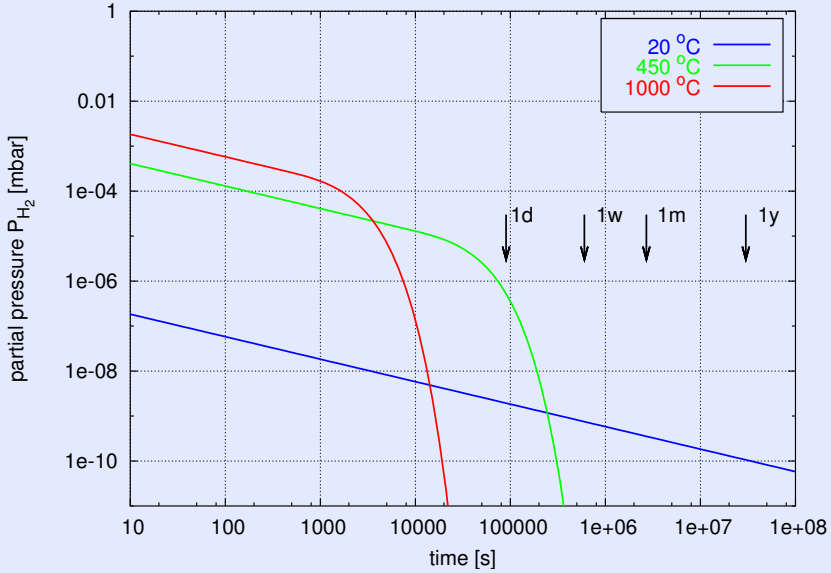


Figure 7. Diffusion constants. (1) H_2–Pd, Barrer; (2) N_2–Fe, Barrer; (3) CO–Ni, Nushman and Lafferty; (4) H_2–Ni, Barrer; (5) H_2–Fe, Barrer; (6) O_2–Ni, Dushman and Lafferty; (8) H_2–stainless steel (300), Eschbach; (9) H_2–stainless steel (400), Eschbach. (Lewin, 1965[15].)

Bulk Diffusion cont'd.

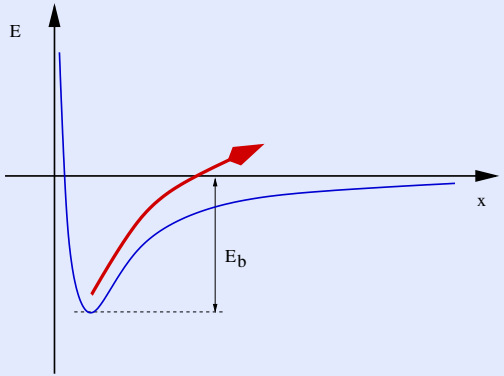
for UHV materials of practical use only H_2 has relevant diffusion speed
a common practice is hydrogen degassing at $\approx 1000°C$

simulation (qualitatively): steel at different temperatures



Surface Gas - Outgassing

- gas molecules are bound to surface



  binding energies below 8 kcal/mol,
- Van der Waals forces
  → called physisorption

- for larger energies called chemisorption

examples of gas-material combinations:

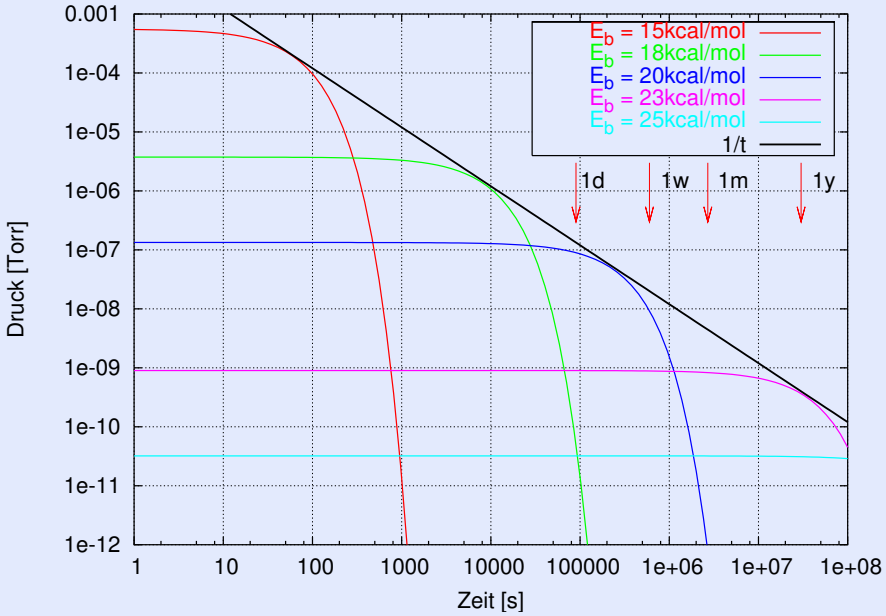
Ar on W	1.9 kcal/mol
H_2 on Cu	8 kcal/mol
CO on Ni	35 kcal/mol

Surface Gas cont'd.

the binding energy E_b determines how fast a surface is pumped down average binding period (*sojourn time*):

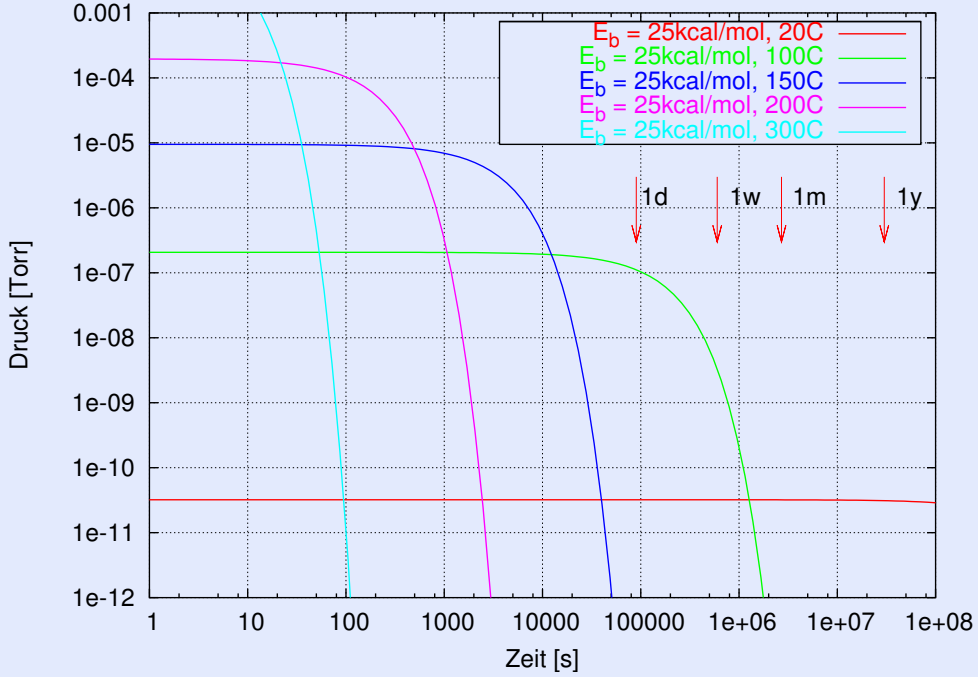
$$t_s = 10^{-13}[s] \cdot \exp\left(\frac{E_b}{R_0 T}\right)$$

- spectrum of E_b often complicated eg. water
- oxide layers, surface topology
- simulation:
  $A = 15000\,\mathrm{cm}^2$
  $S = 15\,\mathrm{l/s}$
  one monolayer



Surface Gas cont'd.

baking can accelerate the pump-down process drastically!
simulation: $E_b = 25\,\mathrm{kcal}$, different temperatures



Procedures and Recommendations

- H_2 degassing is always advantageous in UHV systems
- baking is very important
  $\rightarrow$ pumping at elevated temperatures results in exponentially accelerated conditioning
- the temperature dependence is exponential!
  $\rightarrow$ even small increases of the baking temperature are helpful
- H_2O with its wide spectrum of binding energies is problematic

Recommendations cont'd.

- **conservation** of the conditioning status?
  difficult, filling with **dry Nitrogen** will help but:

  numerical example:

  – volume with $V = 4\,\mathrm{l}$, $A = 1000\,\mathrm{cm}^2$, 0.01 mono-layer H_2O

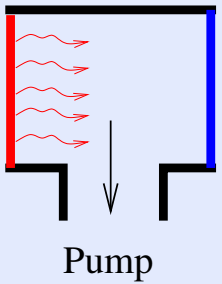
  – this are 10^{16} molecules, $300\,\mathrm{ng}$

  – when released results in $P_{H_2O} \approx 6 \cdot 10^{-4}\,\mathrm{mbar}$!

  $\longrightarrow$ **small contaminations with air will degrade the conditioning state quickly**

Recommendations cont'd.

- **partial baking** (surface A hot, B cold)?



not very helpful! - remember:

we are aiming for orders of magnitude but this would remove only half(?) of the gas

Conclusions

(neglecting other than vacuum aspects!)

- baking around 150 °C for 24 hours would remove the water; higher temperatures 250 °C to 400 °C would efficiently remove strongly bound hydrocarbons
- in-situ baking is the best option
- ideally the same temperature everywhere
- high pumping speed and efficient cross-sections
- careful cleaning and assembly
  this should be unmistakably clear to everybody involved in the production of UHV components!!